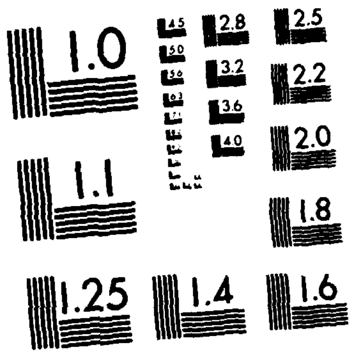
AD-A171 495 DETERMINATION OF THE COEFFICIENT OF THERMAL EXPANSION 1/1
OF JP-4 FUELS(U) MONSANTO CO DAYTON OH DAYTON LAB
D S DUVALL ET AL DEC 85 AFWAL-TR-85-2093
UNCLASSIFIED F33615-81-C-2035 F/G 21/4 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AFWAL-TR-85-2093

DETERMINATION OF THE COEFFICIENT OF THERMAL EXPANSION OF JP-4 FUELS

Donovan S. Duvall, Michael D. Hale, Donald J. Lewis,
and Arthur D. Snyder

MONSANTO COMPANY
DAYTON LABORATORY
DAYTON, OHIO 45407

December 1985

Interim Report for Period April 1983 - July 1985

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION IS UNLIMITED

AERO PROPULSION LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture use, or sell any patented invention that may in any way be related thereto.

This report has been reviewed by the Office of Public Affairs (ASD/PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

Timothy L. Dues

TIMOTHY L. DUES, Project Engineer
Fuels Branch
Fuels and Lubrication Division
Aero Propulsion Laboratory

Charles R. Martel

CHARLES R. MARTEL, Acting Chief
Fuels Branch
Fuels and Lubrication Division
Aero Propulsion Laboratory

Benito P. Botteri

BENITO P. BOTTERI, Asst Chief
Fuels and Lubrication Division
Aero Propulsion Laboratory

"If your address has changed, if you wish to be removed from our mailing list, or if the addressee is no longer employed by your organization, please notify AFWAL/POSF, W-PAFB, OH 45433 to help us maintain a current mailing list."

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY AFWAL/CC 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for Public Release, Distribution is Unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) AFWAL-TR-85-2093
6a. NAME OF PERFORMING ORGANIZATION Monsanto Company Dayton Laboratory 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Aero Propulsion Laboratory (AFWAL/POSF)
6c. ADDRESS (City, State and ZIP Code) 1515 Nicholas Road Dayton, Ohio 45418	7b. ADDRESS (City, State and ZIP Code) AF Wright Aeronautical Laboratories (AFSC) Wright-Patterson Air Force Base, OH 45433
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Fuels & Lubrication Division 8b. OFFICE SYMBOL (If applicable) AFWAL/POS	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F33615-81-C-2035
8c. ADDRESS (City, State and ZIP Code) AF Wright Aeronautical Laboratories (AFSC) Wright-Patterson Air Force Base, OH 45433	10. SOURCE OF FUNDING NOS. PROGRAM ELEMENT NO.: 62203F PROJECT NO.: 3048 TASK NO.: 05 WORK UNIT NO.: 15
11. TITLE (Include Security Classification) Determination of the Coefficient of Thermal Expansion of JP-4 Fuels	
12. PERSONAL AUTHOR(S) D.S. Duvall, M.D. Hale, D.J. Lewis, and A.D. Snyder	
13a. TYPE OF REPORT Interim 13b. TIME COVERED FROM 4/83 TO 7/85	14. DATE OF REPORT (Yr., Mo., Day) 85-12 15. PAGE COUNT 54
16. SUPPLEMENTARY NOTATION	

17. COSATI CODES

FIELD	GROUP	SUB. GR.
21	02	
21	04	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Density, Coefficient of thermal expansion, Jet fuels, Temperature, and Statistical analysis.

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Precise density determinations were made on 100 JP-4 jet fuels using a Mettler/Paar Model ADS-55 density measuring system. Statistical analysis of the density measurements was performed using a computerized nonlinear regression technique; and coefficient of thermal expansion values were calculated for each fuel at 60°F. A majority of the fuels (88 out of 100) were consistent with the API published volume series correction for crude oils.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☒ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Mr. Timothy Dues	22b. TELEPHONE NUMBER (Include Area Code) (513) 255-7295 22c. OFFICE SYMBOL AFWAL/POSF

FOREWORD

This report was submitted by the Monsanto Company under Contract F33615-81-C-2035. This effort was sponsored by the Aero Propulsion Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base, Ohio, as requested by the Defense Fuel Supply Center, Cameron Station, Alexandria, Virginia. Mr. Tim Dues was Contract Monitor, while Dr. Arthur D. Snyder of Monsanto served as Contract Monitor on the study which was performed during the period from April 1983 to July 1985.

The authors gratefully acknowledge the excellent guidance provided by Mr. Tim Dues of Wright-Patterson and Mr. Ronald G. Gomes of the Defense Fuel Supply Center in the performance of this task.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION I

INTRODUCTION AND SUMMARY

1. BACKGROUND

The U.S. Department of Defense expends many billions of dollars annually in its acquisition of petroleum-based fuels.

Refined petroleum products are purchased in standard volumetric units, i.e., the U.S. gallon of 231 cubic inches at 60°F. In order to determine petroleum product volumes consistently with this criterion, it is generally necessary to convert apparent volumes observed at temperatures other than 60°F to volumes corrected to the 60°F standard. The process by which this objective is accomplished involves the use of volume correction factors which permit normalization of product volumes, observed within a wide range of temperatures and fuel densities, to volumes at 60°F. Issues of the petroleum measurement tables published prior to the current (1980) edition were based on technical evaluations of petroleum oils performed between 1912 and 1952.

Investigation of this body of technical data, executed by the American Petroleum Institute (API) in conjunction with the U.S. National Bureau of Standards (NBS), resulted in the publication of revised volume correction tables. These volume correction tables, designated as API standard 2540, ASTM D1250, IP-200, and ISO-91, are predicated upon the volumetric coefficients of thermal expansion, as experimentally determined by the NBS, for various categories of petroleum products, as well as a wide spectrum of crude oils. The current volume correction standard is typically used on a world-wide basis by both public and private sector entities, including the U.S. Department of Defense.

The petroleum volume correction tables are principally divided into four series, designated A through D, inclusively.

The tables termed "A" are devised for use with crude oils; "B" with refined products; "D" with lubricants. The "C" series tables are designed to accommodate experimental determination of the volumetric coefficient of thermal expansion for a specific petroleum oil batch or cargo.

2. PURPOSE OF STUDY

Subsequent to the publication of the current edition of the volume correction tables, the API published guidance concerning the application of the tables to several substances, including Aviation Turbine Fuel, Grade JP-4. Specifically, the guidance advocated the application of the volume correction series prepared for crude oils, viz, "A" for JP-4. In recognition of the fact that; (a) this recommendation was based upon the analysis of relatively few JP-4 samples, and (b) the compositional diversity of JP-4 is extensive, this study was initiated to evaluate the extent to which the use of the "A' series tables for JP-4 is applicable.

3. SUMMARY OF RESULTS

A program was carried out where density data were accurately measured at 10 different temperatures for 100 JP-4 jet fuels. Analytical instrumentation used in this work was a Mettler/Paar Model ADS-55 density measuring system having a precision of 1×10^{-5} gm/cm^3.

Statistical analysis of the density measurements was performed using a computerized nonlinear regression technique. Coefficient of thermal expansion (α) values were calculated for each fuel at 60°F.

A heavy majority of the JP-4 samples (88 out of 100) had α values more consistent with the "A" (crude group), than with the "B" (generalized products group). These findings are in agreement with the API's published guidance concerning the recommended use of table "A" for JP-4 jet fuels.

SECTION II

METHODOLOGY

1. PROCUREMENT/SOURCE OF FUEL SAMPLES

Fuel samples for this program were provided by the Air Force Contract Monitor. The 100 JP-4 samples were selected to represent a significant proportion of that fuel currently being used by the Air Force. The sources of all the fuels used in this program are listed in Appendix A.

2. DENSITY MEASUREMENTS

The scope of the test plan included the determination of density values on approximately 100 JP-4 fuel samples at the following temperatures: 30, 45, 55, 60, 65, 75, 85, 95, 105, and 120°F. Density measurements were conducted with a Mettler/Paar Model ADS-55 density measuring system. This consisted of a Model DMA-55 vibrating tube density meter with an auto-sampler and a constant temperature bath controlling to $\pm$ 0.005°C over the temperature range from -10 to +60°C. The temperature of the sample tube was measured using a precision, hermetically glass-encapsulated thermister which had been calibrated over the -10 to +60°C temperature range at 0.05°C intervals. Temperatures were recorded to the nearest 0.01°C. The precision of the ADS-55 system is 1×10^{-5} g/cm^3. The analytical protocol and test plan were intended to insure that proper calibration and cleanliness were maintained during the entire measurement sequence. The goal was to make sure that measurements at any temperature could be reproduced to within $\pm 3 \times 10^{-5}$ g/cm^3 or better.

An early problem with density measurement was experienced when some of the fuels "bubbled" at the higher temperatures, i.e., 105° and 120°F. Since the density couldn't be accurately measured when boiling had been initiated, a change in technique was required. A successful alteration of the technique involved the elevation of the initial boiling point of the fuel by subjecting it to a small positive pressure. (This could be done since liquid fuels have insignificant compressibilities.) The pressurizing of the cell with 5 psi of N_2 was easily accomplished using a Teflon 3-way rotary valve.

3. DATA ANALYSIS PROCEDURES

History

The American Society for Testing and Materials (ASTM) published the Petroleum Measurement Tables in 1980 in 10 volumes. Most of the following information is taken from Volume X - Background, Development, and Program Documentation. This document, ASTM D 1250-80, also contains theoretical development which is valuable for evaluating these tables.

The original Petroleum Measurement Tables were developed in the late 1940's. In 1972, Downer and Inkley demonstrated that those tables did not provide a satisfactory representation of many petroleum fluids of current interest. As a result, API and the NBS initiated a research program in 1974. This study was funded by the API. The purpose was to "provide the solid scientific base for the development of more accurate, consequently more equitable, measurement tables."

Precise density data were collected on 349 different fluids, "representing a wide variety of refined products and 66.8 percent of the world crude production in 1974." The study was completed

in March 1979 and cost $500,000. A working group was formed to study the results and produce the tables mentioned previously. That work is described by Hankinson et al. (1979).

Unfortunately, the JP-4 type fuels were not very well represented by the API study. Only four such samples were included. The present work was undertaken to better characterize this group and to determine whether the JP-4's properly belonged with the "A" table group (generalized crude oils) or with the "B" table group (generalized products).

Theory

The definition for the coefficient of thermal expansion is

$$\alpha = \frac{1}{V}\frac{dV}{dt} \tag{1}$$

where: α = coefficient of thermal expansion
V = volume at any temperature, and
t = temperature.

The working group chose to use the representation:

$$VCF = \frac{V_T}{V} = \frac{\rho}{\rho_T} = EXP\ -\alpha_T \Delta t[1 + \alpha_T \Delta t(k/2)] \tag{2}$$

where: VCF = volume correction factor
t = any temperature
T = base temperature
α_T = α at the base temperature
Δt = $t - T$
ρ = density at t
ρ_T = density at T
V = volume at t
V_T = volume at T

and k is an empirically derived constant, determined by the committee to be 1.6 to best represent the data. Throughout this study, the base temperature, T, was taken to be 60°F.

Further, the group determined that the coefficients of thermal expansion at the base temperature for each group were related to the densities at the base temperature by:

$$\alpha_T = \frac{K_0 + K_1 \rho_T}{(\rho_T)^2} \tag{3}$$

The data were also examined for internal consistency by computing a percent standard deviation and a maximum percent error. The percent standard deviation is defined by:

$$\sigma = 100\sqrt{\left(\sum_{i=1}^{n_0} \left[(\rho_i - \rho_c)/\rho_i\right]^2/(np-1)\right)} \tag{4}$$

where: σ = percent standard deviation

ρ_i = measured density

ρ_c = calculated density (regression fit)

np = number of points

n_0 = total number of observations in a group.

The maximum percent error is given by:

$$\max_i \left|(\rho_i - \rho_c)/\rho_i\right| / \sigma \tag{5}$$

Analysis of Density Data

The density data for the 100 JP-4 fuel samples were entered into a data base on Monsanto's IBM mainframe computer in St. Louis, Missouri. These data were analyzed using the Statistical Analysis System (SAS), a programming language/statistical analysis package.

Nonlinear regression was used to estimate the parameters in equation 2. The logarithmic form was used, i.e., the model used was:

$$\log(\rho) = \log(\rho_T) - \alpha_T \Delta t[1+\alpha_T \Delta t(k/2)] + e_i \qquad (6)$$

where e_i is a random variation term. In general, the data fit the assumed model very well. The estimates for the parameters had very small standard deviations except for k. This parameter had very little impact on the regression, and it was determined that using the previously assumed value of 1.6 for k did not perceptibly degrade the regression fit. The estimates for α_T and ρ_T are given in tables 1, 2, and 3, sorted by sample number, alpha-t (α_T), and base density (ρ_T), respectively.

Included in each table is the API gravity, given by the equation:

$$°API = (141.5 \times 999.012/\text{base density}) - 131.5 \qquad (7)$$

Also included are the percent standard deviation and the maximum percent error, as shown in equations 4 and 5. A comparison of these values with the appendix to Table 6C, 11.1.6.7.1, shows that the Monsanto data compare very favorably. No statistical tests were performed to determine whether the appendix data and the Monsanto data differ, however. Such tests would not appear appropriate because the Monsanto data cover a much narrower density range. The appendix data also cover varying temperature ranges.

Nonlinear regression was then applied to determine values for K_0 and K_1, using the α_T and ρ_T values shown in the tables to fit equation 3. The nonlinear regression uses an iterative procedure, requiring starting values for the parameters. The values $K_0 = 190$ and $K_1 = 0.3$ were used as starting points, since those are the values used at the low end of the gasoline group, and they have similar API values. The procedure converged quickly to give values

of $K_0 = 300 \pm 59$ and $K_1 = 0.05 \pm 0.08$. Since the K_1 term was non-significant, the nonlinear regression was reapplied, setting K_1 to zero. That regression yielded $K_0 = 341.0 \pm 0.5$. The much smaller standard deviation for K_0 is a result of removing K_1, which was highly correlated with K_0. Based on these observations, K_0 was calculated for each sample as:

$$K_0 = \alpha_T(\rho_T)^2 \qquad (8)$$

The right-most column in the three tables lists either 'JET' or 'CRUDE'. This determination was made based on whether the α_T value was closer to the α_T value determined from equation 3 above using the 'JET' coefficients or the 'CRUDE' coefficients. The 'JET' coefficients are $K_0 = 330.301$ and $K_1 = 0$. The 'CRUDE' coefficients are $K_0 = 341.0957$ and $K_1 = 0$.

TABLE 1. CALCULATED VALUES SORTED BY SAMPLE NUMBER

Sample No.	Alpha x 10^6 at 60°F	Density (kg/m^3)	°API	K_0	Percent standard deviation	Maximum percent error	Nearest Group
541	583.757	760.394	54.4039	337.528	0.0092872	0.022652	CRUDE
585	588.734	763.937	53.5417	343.585	0.0065365	-0.01794	CRUDE
588	562.605	772.659	51.4529	335.876	0.0026834	-0.01882	CRUDE
589	598.096	760.916	54.2764	346.293	0.0034705	-0.015651	CRUDE
590	615.538	752.991	56.2316	349.007	0.0034969	-0.017306	CRUDE
591	585.201	760.259	54.4369	338.243	0.0053033	0.023479	CRUDE
592	583.451	761.772	54.0676	338.575	0.0034801	0.014054	CRUDE
594	574.962	763.858	53.5608	335.478	0.0068791	-0.021578	JET
595	604.953	757.654	55.0762	347.267	0.0031484	0.015481	CRUDE
596	581.223	764.468	53.4132	339.673	0.0014175	-0.014584	CRUDE
597	593.574	766.078	53.0245	348.354	0.0037204	0.019882	CRUDE
598	596.013	758.814	54.791	343.184	0.0039638	0.017863	CRUDE
599	607.348	756.772	55.2936	347.831	0.0036042	0.0171	CRUDE
600	590.813	758.068	54.9743	339.521	0.0036983	-0.016921	CRUDE
601	591.473	769.191	52.2778	349.948	0.0029975	0.013027	CRUDE
602	607.254	752.711	56.3014	344.054	0.0033419	0.016486	CRUDE
603	580.262	762.208	53.9614	337.11	0.004234	-0.017754	CRUDE
604	571.501	764.339	53.4444	333.879	0.003342	0.015522	JET
605	577.965	754.893	55.7586	329.361	0.0015975	-0.014985	JET
608	599.345	759.381	54.6519	345.618	0.0045526	-0.017738	CRUDE
609	585.362	772.715	51.4396	349.513	0.0023455	-0.015108	CRUDE
610	600.342	755.616	55.5794	342.769	0.0030678	0.01493	CRUDE
611	595.527	756.254	55.4216	340.594	0.0029107	-0.018391	CRUDE
612	579.312	764.431	53.4221	338.524	0.0017838	0.015486	CRUDE
613	574.05	769.266	52.2598	339.706	0.0023722	0.019833	CRUDE
614	567.878	771.436	51.7429	337.952	0.0043604	-0.018738	CRUDE
615	593.62	750.708	56.8025	334.542	0.0040095	-0.016136	JET
616	597.029	753.316	56.1506	338.805	0.0045995	-0.016308	CRUDE
617	601.405	752.126	56.4475	340.211	0.0044769	-0.017306	CRUDE
618	595.278	757.726	55.0585	341.778	0.0039377	-0.017219	CRUDE
624	589.087	763.366	53.6801	343.277	0.0043622	-0.017963	CRUDE
625	590.206	757.232	55.1802	338.424	0.0064584	-0.019015	CRUDE
626	593.483	752.631	56.3214	336.18	0.0053988	-0.018465	CRUDE
627	603.207	763.162	53.7296	351.318	0.0043162	-0.017844	CRUDE
628	596.502	753.596	56.0809	338.758	0.0035775	0.020787	CRUDE
629	569.905	771.756	51.667	339.44	0.0135503	0.023324	CRUDE
636	569.182	776.69	50.5034	343.358	0.0043464	0.015334	CRUDE
637	586.634	760.007	54.4985	338.846	0.0195866	-0.023701	CRUDE
638	613.289	752.708	56.3022	347.471	0.0112538	0.022379	CRUDE
639	585.527	767.145	52.7679	344.589	0.0107066	0.022607	CRUDE
643	600.151	754.051	55.9677	341.242	0.0097446	0.023231	CRUDE
644	597.611	760.534	54.3697	345.665	0.0099067	0.02316	CRUDE
914	608.807	756.008	55.4824	347.962	0.0055208	0.020128	CRUDE
915	571.281	779.398	49.871	347.031	0.0041162	-0.017647	CRUDE
916	579.312	763.241	53.7104	337.471	0.0019546	-0.016	CRUDE
917	577.57	762.081	53.9924	335.434	0.0108805	-0.017763	JET
918	594.005	752.906	56.2528	336.722	0.0017513	0.017245	CRUDE
919	594.116	752.328	56.397	336.268	0.0030684	0.016515	CRUDE
920	571.549	780.325	49.6555	348.02	0.0047596	0.017572	CRUDE
921	577.101	769.343	52.2414	341.58	0.0022566	0.01999	CRUDE

TABLE 1 (continued)

Sample No.	Alpha x 10^6 at 60°F	Density (kg/m^3)	°API	K_0	Percent standard deviation	Maximum percent error	Nearest Group
922	573.835	763.667	53.6071	334.653	0.0038613	0.019461	JET
923	580.925	765.46	53.1735	340.381	0.0046753	-0.021039	CRUDE
924	583.025	758.271	54.9244	335.225	0.0043259	-0.016294	JET
925	563.948	772.9	51.3958	336.888	0.0057848	0.021449	CRUDE
926	572.015	766.861	52.8361	336.388	0.0197222	0.02227	CRUDE
927	589.643	759.14	54.711	339.807	0.0044831	-0.016435	CRUDE
928	575.157	767.151	52.7665	338.492	0.0066835	-0.015676	CRUDE
929	579.646	765.697	53.1164	339.842	0.0040857	-0.016849	CRUDE
930	572.244	769.01	52.321	338.412	0.0088048	0.023206	CRUDE
931	578.046	764.943	53.2983	338.237	0.0085534	0.022642	CRUDE
932	557.008	774.292	51.067	333.942	0.0080875	0.020282	JET
933	589.484	757.707	55.0631	338.434	0.0076505	0.018399	CRUDE
934	575.677	766.462	52.9321	338.19	0.0055272	0.022409	CRUDE
935	591.324	773.492	51.2559	353.783	0.0051233	0.01623	CRUDE
936	577.56	765.499	53.1641	338.444	0.0074283	0.019122	CRUDE
937	576.069	777.575	50.2962	348.304	0.0042289	0.018656	CRUDE
938	608.479	754.176	55.9366	346.092	0.0042614	0.018523	CRUDE
939	596.37	756.061	55.4693	340.902	0.0042212	0.017746	CRUDE
940	597.579	764.411	53.427	349.18	0.0079464	0.017269	CRUDE
941	592.74	756.971	55.2445	339.643	0.0069301	0.020606	CRUDE
997	590.478	752.252	56.416	334.142	0.0043057	-0.02004	JET
999	587.699	757.682	55.0693	337.387	0.0034414	-0.019471	CRUDE
1001	583.511	764.74	53.3474	341.253	0.0020502	-0.015637	CRUDE
1019	602.864	756.379	55.3907	344.904	0.0040695	-0.018105	CRUDE
1021	571.679	765.429	53.181	334.936	0.0694174	-0.028105	JET
1087	606.037	760.09	54.4782	350.13	0.0154985	-0.014262	CRUDE
1088	606.037	760.09	54.4782	350.13	0.0063159	-0.020438	CRUDE
1089	584.783	761.356	54.169	338.977	0.0027566	0.019661	CRUDE
1091	592.877	761.874	54.0428	344.137	0.0032064	-0.016656	CRUDE
1093	586.29	755.939	55.4995	335.032	0.0054399	0.013974	JET
1095	589.104	763.599	53.6236	343.497	0.0026258	-0.016592	CRUDE
1096	587.692	763.575	53.6294	342.652	0.0045801	-0.021483	CRUDE
1097	614.811	753.283	56.1588	348.865	0.0031644	0.016485	CRUDE
1157	579.866	761.16	54.2168	335.954	0.0029622	-0.024625	CRUDE
1181	581.682	761.362	54.1675	337.185	0.0027931	0.014941	CRUDE
1283	571.081	768.502	52.4425	337.278	0.0022525	-0.017732	CRUDE
1793	618.307	751.25	56.6667	348.958	0.0031916	-0.019234	CRUDE
1794	583.408	761.152	54.2187	337.999	0.0063782	-0.021453	CRUDE
1795	619.501	756.18	55.4399	354.236	0.0028004	0.019395	CRUDE
1796	589.625	763.362	53.6811	343.587	0.0338125	-0.022537	CRUDE
1954	577.798	762.777	53.8231	336.179	0.0031501	-0.020127	CRUDE
1955	577.431	762.953	53.7803	336.121	0.0034839	0.021313	CRUDE
1956	579.057	762.589	53.8688	336.746	0.0038383	-0.017272	CRUDE
1957	581.515	763.305	53.6949	338.811	0.0028993	0.019533	CRUDE
1958	588.463	760.573	54.3601	340.409	0.0138739	0.024269	CRUDE
1959	582.234	758.211	54.9391	334.717	0.012848	0.023968	JET
1960	610.364	751.451	56.6163	344.659	0.0129409	0.023683	CRUDE
1961	599.391	755.153	55.6941	341.806	0.0022506	0.016022	CRUDE
1962	593.399	753.269	56.1623	336.703	0.0021075	-0.016778	CRUDE
1963	579.99	768.308	52.489	342.366	0.0025856	-0.013189	CRUDE

TABLE 2. CALCULATED VALUES SORTED BY ALPHA

Sample No.	Alpha x 10^6 at 60°F	Density (kg/m^3)	°API	K_0	Percent standard deviation	Maximum percent error	Nearest Group
932	557.008	774.292	51.067	333.942	0.0080875	0.020282	JET
588	562.605	772.659	51.4529	335.876	0.0026834	-0.01882	CRUDE
925	563.948	772.9	51.3958	336.888	0.0057848	0.021449	CRUDE
614	567.878	771.436	51.7429	337.952	0.0043604	-0.018738	CRUDE
636	569.182	776.69	50.5034	343.358	0.0043464	0.015334	CRUDE
629	569.905	771.756	51.667	339.44	0.0135503	0.023324	CRUDE
1283	571.081	768.502	52.4425	337.278	0.0022525	-0.017732	CRUDE
915	571.281	779.398	49.871	347.031	0.0041162	-0.017647	CRUDE
604	571.501	764.339	53.4444	333.879	0.003342	0.015522	JET
920	571.549	780.325	49.6555	348.02	0.0047596	0.017572	CRUDE
1021	571.679	765.429	53.181	334.936	0.0694174	-0.028105	JET
926	572.015	766.861	52.8361	336.388	0.0197222	0.02227	CRUDE
930	572.244	769.01	52.321	338.412	0.0088048	0.023206	CRUDE
922	573.835	763.667	53.6071	334.653	0.0038613	0.019461	JET
613	574.05	769.266	52.2598	339.706	0.0023722	0.019833	CRUDE
594	574.962	763.858	53.5608	335.478	0.0068791	-0.021578	JET
928	575.157	767.151	52.7665	338.492	0.0066835	-0.015676	CRUDE
934	575.677	766.462	52.9321	338.19	0.0055272	0.022409	CRUDE
937	576.069	777.575	50.2962	348.304	0.0042289	0.018656	CRUDE
921	577.101	769.343	52.2414	341.58	0.0022566	0.01999	CRUDE
1955	577.431	762.953	53.7803	336.121	0.0034839	0.021313	CRUDE
936	577.56	765.499	53.1641	338.444	0.0074283	0.019122	CRUDE
917	577.57	762.081	53.9924	335.434	0.0108805	-0.017763	JET
1954	577.798	762.777	53.8231	336.179	0.0031501	-0.020127	CRUDE
605	577.965	754.893	55.7586	329.361	0.0015975	-0.014985	JET
931	578.046	764.943	53.2983	338.237	0.0085534	0.022642	CRUDE
1956	579.057	762.589	53.8688	336.746	0.0038383	-0.017272	CRUDE
916	579.312	763.241	53.7104	337.471	0.0019546	-0.016	CRUDE
612	579.312	764.431	53.4221	338.524	0.0017838	0.015486	CRUDE
929	579.646	765.697	53.1164	339.842	0.0040857	-0.016849	CRUDE
1157	579.866	761.16	54.2168	335.954	0.0029622	-0.024625	CRUDE
1963	579.99	768.308	52.489	342.366	0.0025856	-0.013189	CRUDE
603	580.262	762.208	53.9614	337.11	0.004234	-0.017754	CRUDE
923	580.925	765.46	53.1735	340.381	0.0046753	-0.021039	CRUDE
596	581.223	764.468	53.4132	339.673	0.0014175	-0.014584	CRUDE
1957	581.515	763.305	53.6949	338.811	0.0028993	0.019533	CRUDE
1181	581.682	761.362	54.1675	337.185	0.0027931	0.014941	CRUDE
1959	582.234	758.211	54.9391	334.717	0.012848	0.023968	JET
924	583.025	758.271	54.9244	335.225	0.0043259	-0.016294	JET
1794	583.408	761.152	54.2187	337.999	0.0063782	-0.021453	CRUDE
592	583.451	761.772	54.0676	338.575	0.0034801	0.014054	CRUDE
1001	583.511	764.74	53.3474	341.253	0.0020502	-0.015637	CRUDE
541	583.757	760.394	54.4039	337.528	0.0092872	0.022652	CRUDE
1089	584.783	761.356	54.169	338.977	0.0027566	0.019661	CRUDE
591	585.201	760.259	54.4369	338.243	0.0053033	0.023479	CRUDE
609	585.362	772.715	51.4396	349.513	0.0023455	-0.015108	CRUDE
639	585.527	767.145	52.7679	344.589	0.0107066	0.022607	CRUDE
1093	586.29	755.939	55.4995	335.032	0.0054399	0.013974	JET
637	586.634	760.007	54.4985	338.846	0.0195866	-0.023701	CRUDE
1096	587.692	763.575	53.6294	342.652	0.0045801	-0.021483	CRUDE

TABLE 2 (continued)

Sample No.	Alpha x 10^6 at 60°F	Density (kg/m^3)	°API	K_0	Percent standard deviation	Maximum percent error	Nearest Group
999	587.699	757.682	55.0693	337.387	0.0034414	-0.019471	CRUDE
1958	588.463	760.573	54.3601	340.409	0.0138739	0.024269	CRUDE
585	588.734	763.937	53.5417	343.585	0.0065365	-0.01794	CRUDE
624	589.087	763.366	53.6801	343.277	0.0043622	-0.017963	CRUDE
1095	589.104	763.599	53.6236	343.497	0.0026258	-0.016592	CRUDE
933	589.484	757.707	55.0631	338.434	0.0076505	0.018399	CRUDE
1796	589.625	763.362	53.6811	343.587	0.0338125	-0.022537	CRUDE
927	589.643	759.14	54.711	339.807	0.0044831	-0.016435	CRUDE
625	590.206	757.232	55.1802	338.424	0.0064584	-0.019015	CRUDE
997	590.478	752.252	56.416	334.142	0.0043057	-0.02004	JET
600	590.813	758.068	54.9743	339.521	0.0036983	-0.016921	CRUDE
935	591.324	773.492	51.2559	353.783	0.0051233	0.01623	CRUDE
601	591.473	769.191	52.2778	349.948	0.0029975	0.013027	CRUDE
941	592.74	756.971	55.2445	339.643	0.0069301	0.020606	CRUDE
1091	592.877	761.874	54.0428	344.137	0.0032064	-0.016656	CRUDE
1962	593.399	753.269	56.1623	336.703	0.0021075	-0.016778	CRUDE
626	593.483	752.631	56.3214	336.18	0.0053988	-0.018465	CRUDE
597	593.574	766.078	53.0245	348.354	0.0037204	0.019882	CRUDE
615	593.62	750.708	56.8025	334.542	0.0040095	-0.016136	JET
918	594.005	752.906	56.2528	336.722	0.0017513	0.017245	CRUDE
919	594.116	752.328	56.397	336.268	0.0030684	0.016515	CRUDE
618	595.278	757.726	55.0585	341.778	0.0039377	-0.017219	CRUDE
611	595.527	756.254	55.4216	340.594	0.0029107	-0.018391	CRUDE
598	596.013	758.814	54.791	343.184	0.0039638	0.017863	CRUDE
939	596.37	756.061	55.4693	340.902	0.0042212	0.017746	CRUDE
628	596.502	753.596	56.0809	338.758	0.0035775	0.020787	CRUDE
616	597.029	753.316	56.1506	338.805	0.0045995	-0.016308	CRUDE
940	597.579	764.411	53.427	349.18	0.0079464	0.017269	CRUDE
644	597.611	760.534	54.3697	345.665	0.0099067	0.02316	CRUDE
589	598.096	760.916	54.2764	346.293	0.0034705	-0.015651	CRUDE
608	599.345	759.381	54.6519	345.618	0.0045526	-0.017738	CRUDE
1961	599.391	755.153	55.6941	341.806	0.0022506	0.016022	CRUDE
643	600.151	754.051	55.9677	341.242	0.0097446	0.023231	CRUDE
610	600.342	755.616	55.5794	342.769	0.0030678	0.01493	CRUDE
617	601.405	752.126	56.4475	340.211	0.0044769	-0.017306	CRUDE
1019	602.864	756.379	55.3907	344.904	0.0040695	-0.018105	CRUDE
627	603.207	763.162	53.7296	351.318	0.0043162	-0.017844	CRUDE
595	604.953	757.654	55.0762	347.267	0.0031484	0.015481	CRUDE
1087	606.037	760.09	54.4782	350.13	0.0154985	-0.014262	CRUDE
1088	606.037	760.09	54.4782	350.13	0.0063159	-0.020438	CRUDE
602	607.254	752.711	56.3014	344.054	0.0033419	0.016486	CRUDE
599	607.348	756.772	55.2936	347.831	0.0036042	0.0171	CRUDE
938	608.479	754.176	55.9366	346.092	0.0042614	0.018523	CRUDE
914	608.807	756.008	55.4824	347.962	0.0055208	0.020128	CRUDE
1960	610.364	751.451	56.6163	344.659	0.0129409	0.023683	CRUDE
638	613.289	752.708	56.3022	347.471	0.0112538	0.022379	CRUDE
1097	614.811	753.283	56.1588	348.865	0.0031644	0.016485	CRUDE
590	615.538	752.991	56.2316	349.007	0.0034969	-0.017306	CRUDE
1793	618.307	751.25	56.6667	348.958	0.0031916	-0.019234	CRUDE
1795	619.501	756.18	55.4399	354.236	0.0028004	0.019395	CRUDE

TABLE 3. CALCULATED VALUES SORTED BY DENSITY

Sample No.	Alpha x 10^6 at 60°F	Density (kg/m^3)	°API	K_0	Percent standard deviation	Maximum percent error	Nearest Group
615	593.62	750.708	56.8025	334.542	0.0040095	-0.016136	JET
1793	618.307	751.25	56.6667	348.958	0.0031916	-0.019234	CRUDE
1960	610.364	751.451	56.6163	344.659	0.0129409	0.023683	CRUDE
617	601.405	752.126	56.4475	340.211	0.0044769	-0.017306	CRUDE
997	590.478	752.252	56.416	334.142	0.0043057	-0.02004	JET
919	594.116	752.328	56.397	336.268	0.0030684	0.016515	CRUDE
626	593.483	752.631	56.3214	336.18	0.0053986	-0.018465	CRUDE
638	613.289	752.708	56.3022	347.471	0.0112538	0.022379	CRUDE
602	607.254	752.711	56.3014	344.054	0.0033419	0.016486	CRUDE
918	594.005	752.906	56.2528	336.722	0.0017513	0.017245	CRUDE
590	615.538	752.991	56.2316	349.007	0.0034969	-0.017306	CRUDE
1962	593.399	753.269	56.1623	336.703	0.0021075	-0.016778	CRUDE
1097	614.811	753.283	56.1588	348.865	0.0031644	0.016485	CRUDE
616	597.029	753.316	56.1506	338.805	0.0045995	-0.016308	CRUDE
628	596.502	753.596	56.0809	338.758	0.0035775	0.020787	CRUDE
643	600.151	754.051	55.9677	341.242	0.0097446	0.023231	CRUDE
938	608.479	754.176	55.9366	346.092	0.0042614	0.018523	CRUDE
605	577.965	754.893	55.7586	329.361	0.0015975	-0.014985	JET
1961	599.391	755.153	55.6941	341.806	0.0022506	0.016022	CRUDE
610	600.342	755.616	55.5794	342.769	0.0030678	0.01493	CRUDE
1093	586.29	755.939	55.4995	335.032	0.0054399	0.013974	JET
914	608.807	756.008	55.4824	347.962	0.0055208	0.020128	CRUDE
939	596.37	756.061	55.4693	340.902	0.0042212	0.017746	CRUDE
1795	619.501	756.18	55.4399	354.236	0.0028004	0.019395	CRUDE
611	595.527	756.254	55.4216	340.594	0.0029107	-0.018391	CRUDE
1019	602.864	756.379	55.3907	344.904	0.0040695	-0.018105	CRUDE
599	607.348	756.772	55.2936	347.831	0.0036042	0.0171	CRUDE
941	592.74	756.971	55.2445	339.643	0.0069301	0.020606	CRUDE
625	590.206	757.232	55.1802	338.424	0.0064584	-0.019015	CRUDE
595	604.953	757.654	55.0762	347.267	0.0031484	0.015481	CRUDE
999	587.699	757.682	55.0693	337.387	0.0034414	-0.019471	CRUDE
933	589.484	757.707	55.0631	338.434	0.0076505	0.018399	CRUDE
618	595.278	757.726	55.0585	341.778	0.0039377	-0.017219	CRUDE
600	590.813	758.068	54.9743	339.521	0.0036983	-0.016921	CRUDE
1959	582.234	758.211	54.9391	334.717	0.012848	0.023968	JET
924	583.025	758.271	54.9244	335.225	0.0043259	-0.016294	JET
598	596.013	758.814	54.791	343.184	0.0039638	0.017863	CRUDE
927	589.643	759.14	54.711	339.807	0.0044831	-0.016435	CRUDE
608	599.345	759.381	54.6519	345.618	0.0045526	-0.017738	CRUDE
637	586.634	760.007	54.4985	338.846	0.0195866	-0.023701	CRUDE
1087	606.037	760.09	54.4782	350.13	0.0154985	-0.014262	CRUDE
1088	606.037	760.09	54.4782	350.13	0.0063159	-0.020438	CRUDE
591	585.201	760.259	54.4369	338.243	0.0053033	0.023479	CRUDE
541	583.757	760.394	54.4039	337.528	0.0092872	0.022652	CRUDE
644	597.611	760.534	54.3697	345.665	0.0099067	0.02316	CRUDE
1958	588.463	760.573	54.3601	340.409	0.0138739	0.024269	CRUDE
589	598.096	760.916	54.2764	346.293	0.0034705	-0.015651	CRUDE
1794	583.408	761.152	54.2187	337.999	0.0063782	-0.021453	CRUDE
1157	579.866	761.16	54.2168	335.954	0.0029622	-0.024625	CRUDE
1089	584.783	761.356	54.169	338.977	0.0027566	0.019661	CRUDE

TABLE 3 (continued)

Sample No.	Alpha x 10^6 at 60°F	Density (kg/m^3)	°API	K_0	Percent standard deviation	Maximum percent error	Nearest Group
1181	581.682	761.362	54.1675	337.185	0.0027931	0.014941	CRUDE
592	583.451	761.772	54.0676	338.575	0.0034801	0.014054	CRUDE
1091	592.877	761.874	54.0428	344.137	0.0032064	-0.016656	CRUDE
917	577.57	762.081	53.9924	335.434	0.0108805	-0.017763	JET
603	580.262	762.208	53.9614	337.11	0.004234	-0.017754	CRUDE
1956	579.057	762.589	53.8688	336.746	0.0038383	-0.017272	CRUDE
1954	577.798	762.777	53.8231	336.179	0.0031501	-0.020127	CRUDE
1955	577.431	762.953	53.7803	336.121	0.0034839	0.021313	CRUDE
627	603.207	763.162	53.7296	351.318	0.0043162	-0.017844	CRUDE
916	579.312	763.241	53.7104	337.471	0.0019546	-0.016	CRUDE
1957	581.515	763.305	53.6949	338.811	0.0028993	0.019533	CRUDE
1796	589.625	763.362	53.6811	343.587	0.0338125	-0.022537	CRUDE
624	589.087	763.366	53.6801	343.277	0.0043622	-0.017963	CRUDE
1096	587.692	763.575	53.6294	342.652	0.0045801	-0.021483	CRUDE
1095	589.104	763.599	53.6236	343.497	0.0026258	-0.016592	CRUDE
922	573.835	763.667	53.6071	334.653	0.0038613	0.019461	JET
594	574.962	763.858	53.5608	335.478	0.0068791	-0.021578	JET
585	588.734	763.937	53.5417	343.585	0.0065365	-0.01794	CRUDE
604	571.501	764.339	53.4444	333.879	0.003342	0.015522	JET
940	597.579	764.411	53.427	349.18	0.0079464	0.017269	CRUDE
612	579.312	764.431	53.4221	338.524	0.0017838	0.015486	CRUDE
596	581.223	764.468	53.4132	339.673	0.0014175	-0.014584	CRUDE
1001	583.511	764.74	53.3474	341.253	0.0020502	-0.015637	CRUDE
931	578.046	764.943	53.2983	338.237	0.0085534	0.022642	CRUDE
1021	571.679	765.429	53.181	334.936	0.0694174	-0.028105	JET
923	580.925	765.46	53.1735	340.381	0.0046753	-0.021039	CRUDE
936	577.56	765.499	53.1641	338.444	0.0074283	0.019122	CRUDE
929	579.646	765.697	53.1164	339.842	0.0040857	-0.016849	CRUDE
597	593.574	766.078	53.0245	348.354	0.0037204	0.019882	CRUDE
934	575.677	766.462	52.9321	338.19	0.0055272	0.022409	CRUDE
926	572.015	766.861	52.8361	336.388	0.0197222	0.02227	CRUDE
639	585.527	767.145	52.7679	344.589	0.0107066	0.022607	CRUDE
928	575.157	767.151	52.7665	338.492	0.0066835	-0.015676	CRUDE
1963	579.99	768.308	52.489	342.366	0.0025856	-0.013189	CRUDE
1283	571.081	768.502	52.4425	337.278	0.0022525	-0.017732	CRUDE
930	572.244	769.01	52.321	338.412	0.0088048	0.023206	CRUDE
601	591.473	769.191	52.2778	349.948	0.0029975	0.013027	CRUDE
613	574.05	769.266	52.2598	339.706	0.0023722	0.019833	CRUDE
921	577.101	769.343	52.2414	341.58	0.0022566	0.01999	CRUDE
614	567.878	771.436	51.7429	337.952	0.0043604	-0.018738	CRUDE
629	569.905	771.756	51.667	339.44	0.0135503	0.023324	CRUDE
588	562.605	772.659	51.4529	335.876	0.0026834	-0.01882	CRUDE
609	585.362	772.715	51.4396	349.513	0.0023455	-0.015108	CRUDE
925	563.948	772.9	51.3958	336.888	0.0057848	0.021449	CRUDE
935	591.324	773.492	51.2559	353.783	0.0051233	0.01623	CRUDE
932	557.008	774.292	51.067	333.942	0.0080875	0.020282	JET
636	569.182	776.69	50.5034	343.358	0.0043464	0.015334	CRUDE
937	576.069	777.575	50.2962	348.304	0.0042289	0.018656	CRUDE
915	571.281	779.398	49.871	347.031	0.0041162	-0.017647	CRUDE
920	571.549	780.325	49.6555	348.02	0.0047596	0.017572	CRUDE

SECTION III

RESULTS AND DISCUSSION

1. DENSITY OF FUELS

Density measurements were made at 10 temperatures for each of 104 JP-4 samples. (There were four sets of blind duplicates, so data were assessed on 100 JP-4 fuels.) The temperature ranged from about 30°F to about 120°F.

Density measurements on JP-4 fuel made during this program are compiled in Appendix B. For each fuel sample the following information is given: (1) fuel number designation; (2) the correlation coefficient for a linear least squares fit of the data; (3) the density value at 60°F calculated from the least squares equation; and (4) the density values for 10 temperatures ranging from ∿30°F to ∿120°F. It can be observed that the linear correlations of these data are excellent with most values being -0.9999, or better.

An additional set of 24 miscellaneous fuels were submitted for analysis. Density measurements made on them are compiled in Appendix C. Coefficient of thermal expansion values were calculated at 60°F and are listed in Appendix D.

Problems were encountered with some of the samples. A shale crude sample, 82-POSF-0325, was so viscous that it was not possible for an aliquot to be drawn up into the instrument for analysis. Two gasoline samples, 84-POSF-2078 and 84-POSF-2079, were so volatile that density measurements could not be made because of "bubbling" even at low temperatures. A third gasoline, 84-POSF-2080, behaved very strangely. Vaporization was observed

at ∿60 and 65°F, and then again at ∿105 and 120°F. Density measurements were made at the other 6 temperatures. A reasonably good correlation coefficient was obtained from these results, and a density at 60°F was calculated.

2. COEFFICIENT OF THERMAL EXPANSION

As is evident from examining either Table 1, 2, or 3, most of the samples have α_T values more consistent with the 'CRUDE' group (88 to 12 for JP-4 jet fuels). Referring back to equation 3, Section II, this is equivalent to saying that K_0 values, for the most part, lie nearer to 341.0957 than to 330.301.

Figures 1 and 2 are "stem and leaf" plots for the α_T and K_0 values, respectively, which show a graphical representation of the frequency distribution of the α_T and K_0 values for the 100 JP-4 samples.

Figure 3 is a plot of the coefficient of expansion (α_T) versus density (ρ_T) at 60°F. A careful examination of the plot reveals that although the plot is reasonably linear, there is some grouping of points by geographical location (number in parentheses in plot indicates geographical district as defined in Table 4). An example of this is that most of the District 5 samples have a higher ρ_T/α_T ratio than most of the other fuel samples.

Stem	Leaf[a]
62	0
61	568
61	03
60	5667789
60	00133
59	56667788899
59	000011133334444
58	555667888999
58	00001122233344
57	5566778888899
57	0112222244
56	89
56	34
55	7

[a]Multiply STEM LEAF by 10.

Note: Each digit in the leaf section represents an alpha data point. [For example, the 56 Stem and Leaf 3, 4, 8, 9 represent 4 data points: 1 between 562.5 and 563.5; 1 between 563.5 and 564.5; 1 between 567.5 and 568.5; and 1 between 568.5 and 569.5]

Figure 1. Stem and Leaf plot of alpha values at 60°F.

Stem	Leaf[a]
354	2
353	8
352	
351	3
350	11
349	00259
348	00349
347	0358
346	13
345	67
344	11679
343	234566
342	478
341	23688
340	24469
339	04567788
338	0022244445568888
337	123455
336	0122347779
335	02459
334	15779
333	99
332	
331	
330	
329	4

Note: Each digit in the leaf section represents a K_0 data point. [For example, the 342 Stem, and Leaf 4, 7, 8 represent 3 data points: 1 between 342.35 and 342.45; 1 between 342.65 and 342.75; and 1 between 342.75 and 342.85]

Figure 2. Stem and leaf plot of K_0 values.

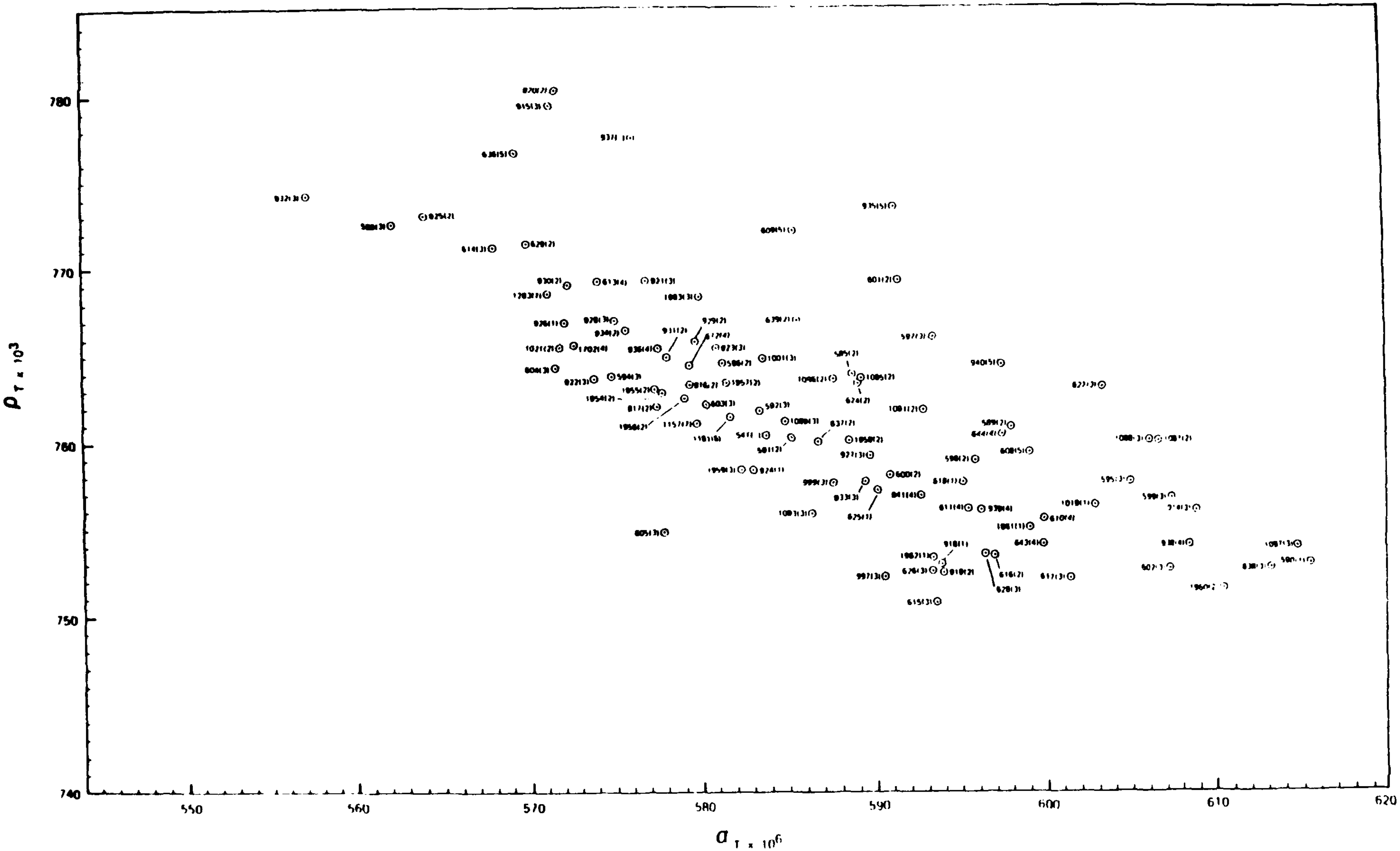


Figure 3. Plot of coefficient of expansion versus density at 60°F.

TABLE 4. GEOGRAPHICAL DISTRICTS

District 1 East Coast	District 2 Midwest	District 3 South	Rocky Mountain	District 5 Pacific	District 6 Far East	District 7	District 8
Connecticut	Illinois	Alabama	Colorado	Arizona	Guam	Europe	South America
Delaware	Indiana	Arkansas	Idaho	California	Singapore	Near East	West Indies
District of Col.	Iowa	Louisiana	Montana	Nevada	Japan	Africa	Canada
Florida	Kansas	Mississippi	Utah	Oregon			Virgin Islands
Georgia	Kentucky	New Mexico	Wyoming	Washington			
Maine	Michigan	Texas		Alaska			
Maryland	Minnesota			Hawaii			
Massachusetts	Missouri						
New Hampshire	Nebraska						
New Jersey	North Dakota						
New York	Ohio						
North Carolina	Oklahoma						
Pennsylvania	South Dakota						
Rhode Island	Tennessee						
South Carolina	Wisconsin						
Vermont							
West Virginia							
Virginia							

SECTION IV

CONCLUSIONS

The data for the 100 JP-4 fuel samples showed good consistency, both internally and with previous work. The samples by a count of 88 to 12 agree more closely with the generalized crude oil tables ("A" series tables) than with the generalized product tables ("B" series tables). The data also show that base density alone is not enough to determine the "correct" thermal expansion coefficient.

SECTION V

REFERENCES

1. Downer, L. and F. A. Inkley, Oil and Gas Journal, 70, No. 25, p. 52-55, June 19, 1972.

2. Hankinson, R. W., R. G. Segers, T. K. Buck, and F. P. Gielzecki, Oil and Gas Journal, 77, No. 52, p. 66-70, December 24, 1979.

APPENDIX A

SOURCE OF FUEL SAMPLES

82-POSF-0541
JP-4, GEFC-1A
J79 Low Smoke

MRC-585
JP-4
Indiana Fuel & Asphalt, Hammond, IN

MRC-588
JP-4
Amber Refining Inc. Refining Co.
Winston, Fort Worth, TX

MRC-589
JP-4
Amoco, Whiting, IN

MRC-590
JP-4
Cibro Petroleum Products, Inc.
Port of Albany, NY

MRC-591
JP-4
Ashland Petroleum Co.
St. Paul Park, MN

MRC-592
JP-4
Pride Refining Co., Abilene, TX

MRC-594
JP-4
Mobil Oil, Beaumont TX

MRC-595
JP-4
Chevron USA, El Paso, TX

MRC-596
JP-4
Allied Materials Corp., Shoud, OK

MRC-597
JP-4
Navajo, Artesia, NM

MRC-598
JP-4
Delta, Memphis, TN

MRC-599
JP-4
Cities Service, Inc.,
Lake Charles, LA

MRC-600
JP-4
Conoco, Inc., Ponca City, OK

MRC-601
JP-4
Conoco, Inc., Ponca City, OK

MRC-602
JP-4
Calcasien Refining Co., CPI
Lake Charles, LA

MRC-603
JP-4
Berry Refining Co., Stevens, AR

MRC-604
JP-4
Atlas Processing Co., Shreveport, LA

MRC-605
JP-4
Southland Oil Co., Sonderville, MS

MRC-608
JP-4
Golden Eagle, Carson City, CA

MRC-609
JP-4
Arco, Los Angeles, CA

MRC-610
JP-4
Amoco, Salt Lake City, UT

MRC-611
JP-4
Amoco, Boise, ID

MRC-612
JP-4
Simons Oil Co., Black Eagle, MT

MRC-613
JP-4
Exxon Company, USA Refining Dept.
Billings, MT

MRC-614
JP-4
Coastal States Ret. Chem.,
Corpus Christie, TX

MRC-615
JP-4
Koch Refining, Corpus Christie, TX

MRC-616
JP-4
Lakeshore Terminal Co.,
Harrisville, MI

MRC-617
JP-4
Chevron USA, Inc., Pascagoula, MS

MRC-618
JP-4
Getty, Delaware City, DE

MRC-624
JP-4
Laketon Asphalt, Inc., Laketon, IN

MRC-625
JP-4
Delaware Storage & Pipeline,
Dover, DE

MRC-626
JP-4
Hunt Oil, Tuscaloosa, AL

MRC-627
JP-4
Howell Hydrocarbons, San Antonia, TX

MRC-628
JP-4
Exxon, Baton Rouge, LA

MRC-629
JP-4
Crystal Refining Co.,
Carson City, MI

MRC-636
JP-4
Mobil Torrence Refining,
Norwalk, CA

MRC-637
JP-4
McConnel AFB, KS

MRC-638
JP-4
Pioneer Refining Ltd., Nixon, TX

MRC-639
JP-4
Amoco Oil Co., Des Moines, IA

MRC-643
JP-4
Chevron USA, Salt Lake Refining,
Salt Lake City, UT

MRC-644
JP-4
Phillips Petroleum Co.,
Wood Crossing, UT

83-POSF-0914
JP-4
Chevron, El Paso, TX

83-POSF-0915
JP-4
Copano, Corpus Christie, TX

83-POSF-0916
JP-4
Allied, Oklahoma City, OK

83-POSF-0917
JP-4
Industrial Fuel & Asphalt, Whiting, IN

83-POSF-0918
JP-4
Getty, Delaware City, DE

83-POSF-0919
JP-4
Gladieux, Fort Wayne, IN

83-POSF-0920
JP-4
Contractor unknown, Milwaukee, WI

83-POSF-0921
JP-4
Hunt Pan Am, Corpus Christie, TX

83-POSF-0922
JP-4
Sun, Corpus Christie, TX

83-POSF-0923
JP-4
Pioneer, San Antonio, TX

83-POSF-0924
JP-4
Sun Petroleum, Marcus Hook, PA

83-POSF-0925
JP-4
Peerless, Grand Rapids, MI

83-POSF-0926
JP-4
Ashland, Buffalo, NY

83-POSF-0927
JP-4
Aviall, Fort Worth, TX

83-POSF-0928
JP-4
Exxon, Baton Rouge, LA

83-POSF-0929
JP-4
Ashland, Louisville, KY

83-POSF-0930
JP-4
Oklahoma Ref., Oklahoma City, OK

83-POSF-0931
JP-4
Tonkawa Ref., Oklahoma City, OK

83-POSF-0932
JP-4
Berry, Shreveport, LA

83-POSF-0933
JP-4
Winson Ref., Fort Worth, TX

83-POSF-0934
JP-4
Allied, Oklahoma City, OK

83-POSF-0935
JP-4
Hawaiian Ind. Ewa Beach, Hawaii

83-POSF-0936
JP-4
Amoco, Salt Lake City, UT

83-POSF-0937
JP-4
Arco-Watson Refinery

83-POSF-0938
JP-4
Phillips, Wood Cross, UT

83-POSF-0939
JP-4
Wyoming Ref., Newcastle, WY

83-POSF-0940
JP-4
Exxon, Benicia, CA

83-POSF-0941
JP-4
Conoco, Commerce City, CO

83-POSF-0997
JP-4
Koch, Corpus Christie, TX

83-POSF-0999
JP-4
Coastal States, Corpus Christie, TX

83-POSF-1001
JP-4
Exxon, Baton Rouge, LA

83-POSF-1019
JP-4
Getty, Delaware City, DE

83-POSF-1021
JP-4
Oklahoma Ref., Oklahoma City, OK

83-POSF-1087
WPAFB, Dayton, OH

83-POSF-1088
JP-4
Howell, San Antonio, TX

83-POSF-1089
JP-4
Amarillo ACFT, Amarillo, TX
aka: 83-POSF-1090

83-POSF-1090
JP-4
Amarillo, ACFT, Amarillo, TX
aka: 83-POSF-1089

83-POSF-1091
JP-4
Amoco, Whiting, IN
aka: 83-POSF-1092

83-POSF-1092
JP-4
Amoco, Whiting, IN

83-POSF-1093
JP-4
Pioneer, Nixon, TX
aka: 83-POSF-1094

83-POSF-1094
JP-4
Pioneer, Nixon, TX

83-POSF-1095
JP-4
WPAFB, Dayton, OH

83-POSF-1096
JP-4
Laketon, Laketon, IN

83-POSF-1097
JP-4
Amerada Hess, Houston, TX
aka: 83-POSF-1098 Duplicate (2)

83-POSF-1098
JP-4
Amerada Hess, Houston, TX

84-POSF-1157
JP-4
Hahn AFB, Germany

83-POSF-1181
JP-4
Osan AFB, Korea

83-POSF-1283
JP-4
Camp New Amsterdam, The Netherlands

83-POSF-1793
JP-4
Amoco, Whiting, IN

83-POSF-1794
JP-4
Mobil, Beaumont, TX

84-POSF-1795
JP-4
Howell, San Antonio, TX

84-POSF-1796
JP-4
Continental, Laurel, DE

84-POSF-1954
JP-4
Continental Services, Escanaba, MI

84-POSF-1955
JP-4
Continental Services, Escanaba, MI

83-POSF-1956
JP-4
Continental Services, Escanaba, MI

84-POSF-1957
JP-4
Oklahoma Ref., Oklahoma City, OK

84-POSF-1958
JP-4
Triangle Ref., St. Louis, MO

84-POSF-1959
JP-4
S. T. Services, Elmendorf, TX

84-POSF-1960
JP-4
Gladieux Ref., Ft. Wayne, IN

84-POSF-1961
JP-4
Getty, Delaware City, DE

84-POSF-1962
JP-4
Sun Ref., Marcus Hook, PA

84-POSF-1963
JP-4
Giant Ref., Gallup, NM

APPENDIX B

TEMPERATURE-DENSITY DATA ON 100 JP-4 FUEL SAMPLES

82-POSF-0541		585[a]		588[a]		589[a]	
Calculated at 60°F = 0.76036		Calculated at 60°F = 0.76390		Calculated at 60°F = 0.77263		Calculated at 60°F = 0.76088	
Correlation = -0.999986		Correlation = -0.999994		Correlation = -0.999989		Correlation = -0.999992	
°F	ρ	°F	ρ	°F	ρ	°F	ρ
32.87	0.77254	32.89	0.77612	32.89	0.78439	32.89	0.77321
45.19	0.76685	44.88	0.77077	44.91	0.77922	44.91	0.76780
54.76	0.76265	55.24	0.76602	55.24	0.77471	55.24	0.76305
59.90	0.76043	60.23	0.76384	60.23	0.77252	60.23	0.76077
65.09	0.75809	64.39	0.76194	64.39	0.77075	64.38	0.75890
74.90	0.75376	74.82	0.75721	74.82	0.76622	74.82	0.75419
85.02	0.74923	84.64	0.75272	84.64	0.76191	84.64	0.74964
95.20	0.74471	95.47	0.74792	95.43	0.75719	95.47	0.74468
105.11	0.74026	104.39	0.74387	104.39	0.75324	104.39	0.74057
119.60	0.73368	119.54	0.73692	119.54	0.74651	119.55	0.73355

590[a]		591[a]		592[a]		594[a]	
Calculated at 60°F = 0.75296		Calculated at 60°F = 0.76023		Calculated at 60°F = 0.76174		Calculated at 60°F = 0.76383	
Correlation = -0.999986		Correlation = -0.999994		Correlation = -0.999983		Correlation = -0.999978	
°F	ρ	°F	ρ	°F	ρ	°F	ρ
33.10	0.76536	32.89	0.77224	32.89	0.77373	32.90	0.77565
45.13	0.75987	44.91	0.76705	44.91	0.76845	44.91	0.77049
54.75	0.75542	55.24	0.76233	55.24	0.76388	55.24	0.76594
60.20	0.75290	60.23	0.76016	60.23	0.76170	60.23	0.76380
65.25	0.75055	64.38	0.75827	64.38	0.75984	64.38	0.76199
75.10	0.74599	74.82	0.75365	74.82	0.75520	74.82	0.75734
84.77	0.74149	84.64	0.74922	84.64	0.75075	84.64	0.75288
94.59	0.73690	95.47	0.74439	95.47	0.74595	95.76	0.74808
105.07	0.73193	104.39	0.74039	104.39	0.74189	104.39	0.74427
119.88	0.72491	119.55	0.73351	119.55	0.73502	119.55	0.73743

[a] These samples were also used in Contract F08635-85-C-0067, "Distillate Fuel Variability".

(continued)

595[a]	
Calculated at 60°F = 0.76444	
Correlation = -0.999985	
°F	ρ
32.90	0.76999
44.91	0.76458
55.24	0.75981
60.23	0.75753
64.38	0.75565
74.82	0.75088
84.64	0.74630
95.47	0.74132
104.39	0.73716
119.55	0.73006

596[a]	
Calculated at 60°F = 0.75762	
Correlation = -0.999991	
°F	ρ
32.90	0.77645
44.91	0.77117
55.24	0.76657
60.23	0.76435
64.38	0.76252
74.82	0.75788
84.64	0.75348
95.39	0.74864
104.39	0.74461
119.55	0.73775

597[a]	
Calculated at 60°F = 0.76604	
Correlation = -0.999985	
°F	ρ
32.34	0.77860
45.07	0.77283
55.27	0.76822
59.70	0.76618
65.11	0.76374
74.99	0.75930
84.84	0.75476
94.94	0.75012
104.20	0.74581
120.09	0.73846

598[a]	
Calculated at 60°F = 0.75878	
Correlation = -0.999982	
°F	ρ
32.34	0.77126
45.07	0.76552
55.27	0.76095
59.70	0.75893
65.11	0.75649
74.99	0.75207
84.84	0.74755
94.94	0.74296
104.20	0.73866
120.09	0.73133

599[a]	
Calculated at 60°F = 0.75673	
Correlation = -0.999985	
°F	ρ
32.34	0.76941
45.07	0.76359
55.27	0.75893
59.70	0.75688
65.11	0.75440
74.99	0.74991
84.84	0.74531
94.94	0.74064
104.20	0.73631
120.09	0.72885

600[a]	
Calculated at 60°F = 0.75804	
Correlation = -0.999985	
°F	ρ
32.34	0.77041
45.07	0.76472
55.27	0.76019
59.70	0.75819
65.29	0.75573
74.99	0.75137
84.84	0.74690
94.94	0.74237
104.20	0.73813
120.09	0.73086

601[a]	
Calculated at 60°F = 0.76916	
Correlation = -0.999987	
°F	ρ
32.34	0.78173
45.07	0.77594
55.27	0.77132
59.70	0.76930
65.29	0.76681
74.99	0.76237
84.84	0.75785
94.94	0.75323
104.20	0.74893
120.09	0.74156

602[a]	
C alculated at 60°F = 0.75268	
Correlation = -0.999985	
°F	ρ
33.10	0.76491
45.13	0.75951
54.75	0.75515
60.20	0.75260
65.25	0.75030
75.10	0.74577
84.77	0.74135
94.59	0.73683
105.07	0.73196
119.88	0.72504

(continued)

603[a]	
Calculated at	
60°F = 0.76218	
Correlation = -0.999985	
°F	ρ
33.10	0.77403
45.13	0.76878
54.75	0.76456
60.20	0.76211
65.25	0.75988
75.10	0.75550
84.77	0.75122
94.59	0.74686
105.07	0.74216
119.88	0.73543

604[a]	
Calculated at	
60°F = 0.76431	
Correlation = -0.999986	
°F	ρ
33.10	0.77600
45.13	0.77082
54.75	0.76667
60.20	0.76427
65.25	0.76203
75.10	0.75770
84.77	0.75347
94.59	0.74918
105.07	0.74451
119.88	0.73791

605[a]	
Calculated at	
60°F = 0.75486	
Correlation = -0.999992	
°F	ρ
33.10	0.76658
45.13	0.76137
54.75	0.75719
60.20	0.75480
65.25	0.75259
75.10	0.74827
84.77	0.74403
94.59	0.73973
105.07	0.73510
119.88	0.72851

608[a]	
Calculated at	
60°F = 0.75935	
Correlation = -0.999978	
°F	ρ
32.34	0.77189
45.07	0.76613
55.27	0.76152
59.70	0.75949
65.29	0.75701
74.99	0.75258
84.84	0.74805
94.94	0.74342
104.20	0.73912
120.09	0.73170

609[a]	
Calculated at	
60°F = 0.77268	
Correlation = -0.999988	
°F	ρ
33.10	0.78482
45.17	0.77940
54.75	0.77511
60.20	0.77260
65.25	0.77033
75.10	0.76586
84.77	0.76148
94.59	0.75700
105.07	0.75219
119.88	0.74534

610[a]	
Calculated at	
60°F = 0.75558	
Correlation = -0.999984	
°F	ρ
33.10	0.76773
45.17	0.76230
54.75	0.75803
60.20	0.75555
65.26	0.75322
75.13	0.74874
84.76	0.74433
94.58	0.73985
105.07	0.73503
119.88	0.72815

611[a]	
Calculated at	
60°F = 0.75622	
Correlation = -0.999984	
°F	ρ
33.10	0.76829
45.17	0.76289
54.75	0.75863
60.20	0.75617
65.26	0.75389
75.13	0.74944
84.76	0.74505
94.58	0.74062
105.07	0.73581
119.88	0.72898

612[a]	
Calculated at	
60°F = 0.76440	
Correlation = -0.999989	
°F	ρ
33.10	0.77629
45.17	0.77096
54.75	0.76677
60.20	0.76434
65.26	0.76209
75.13	0.75772
84.76	0.75342
94.58	0.74905
105.07	0.74433
119.88	0.73764

(continued)

613[a]		614[a]		615[a]		616[a]	
Calculated at 60°F = 0.76923		Calculated at 60°F = 0.77141		Calculated at 60°F = 0.75068		Calculated at 60°F = 0.75328	
Correlation = -0.999987		Correlation = -0.999986		Correlation = -0.999982		Correlation = -0.999978	
°F	ρ	°F	ρ	°F	ρ	°F	ρ
32.34	0.78142	32.34	0.78353	33.10	0.76262	32.34	0.76565
45.08	0.77582	45.08	0.77793	45.17	0.75725	45.08	0.76001
55.28	0.77136	55.28	0.77349	54.75	0.75309	55.28	0.75547
59.71	0.76938	59.71	0.77150	60.20	0.75061	59.71	0.75343
64.98	0.76705	64.98	0.76926	65.26	0.74836	64.98	0.75105
74.98	0.76267	74.98	0.76488	75.13	0.74399	74.98	0.74660
84.81	0.75828	84.81	0.76055	84.76	0.73963	84.81	0.74213
94.92	0.75377	94.92	0.75609	94.58	0.73523	94.92	0.73756
104.20	0.74960	104.20	0.75194	105.07	0.73046	104.20	0.73329
120.04	0.74248	120.04	0.74485	119.88	0.72373	120.04	0.72599

617[a]		618[a]		624[a]		625[a]	
Calculated at 60°F = 0.75209		Calculated at 60°F = 0.75769		Calculated at 60°F = 0.76333		Calculated at 60°F = 0.75720	
Correlation = -0.999978		Correlation = -0.999979		Correlation = -0.999978		Correlation = -0.999970	
°F	ρ	°F	ρ	°F	ρ	°F	ρ
32.34	0.76453	33.10	0.76976	32.97	0.77542	32.97	0.76918
45.08	0.75885	45.47	0.76423	45.20	0.76997	45.20	0.76382
55.28	0.75428	54.75	0.76012	54.71	0.76576	54.71	0.75959
59.71	0.75227	60.20	0.75766	59.91	0.76343	59.91	0.75733
64.98	0.74985	65.26	0.75535	65.09	0.76108	65.09	0.75496
74.98	0.74538	75.13	0.75090	74.90	0.75669	74.90	0.75058
84.81	0.74085	84.76	0.74654	85.02	0.75208	85.02	0.74601
94.92	0.73627	94.58	0.74205	95.20	0.74747	95.20	0.74146
104.20	0.73200	105.07	0.73725	105.12	0.74293	105.12	0.735[illegible]4
120.04	0.72464	119.88	0.73040	119.59	0.73625	119.59	0.73025

(continued)

626[a]		627[a]		628[a]		629[a]	
Calculated at 60°F = 0.75260		Calculated at 60°F = 0.76313		Calculated at 60°F = 0.75356		Calculated at 60°F = 0.77167	
Correlation = -0.999975		Correlation = -0.999978		Correlation = -0.999984		Correlation = -0.999988	
°F	ρ	°F	ρ	°F	ρ	°F	ρ
32.97	0.76460	32.97	0.77549	32.34	0.76597	32.34	0.78380
45.20	0.75921	45.20	0.76995	45.08	0.76027	45.08	0.77820
54.71	0.75497	54.71	0.76559	55.28	0.75570	55.28	0.77376
59.91	0.75273	59.91	0.76325	59.71	0.75371	59.71	0.77179
65.09	0.75035	65.09	0.76083	64.98	0.75134	64.98	0.76946
74.90	0.74597	74.90	0.75630	74.98	0.74690	74.98	0.76516
85.02	0.74143	85.02	0.75160	84.81	0.74240	84.81	0.76080
95.20	0.73686	95.20	0.74687	94.92	0.73783	94.92	0.75635
105.12	0.73234	105.12	0.74226	104.20	0.73359	104.20	0.75222
119.59	0.72568	119.59	0.73540	120.04	0.72630	120.04	0.74512

636[a]		637[a]		638[a]		639[a]	
Calculated at 60°F = 0.77666		Calculated at 60°F = 0.76001		Calculated at 60°F = 0.75267		Calculated at 60°F = 0.76711	
Correlation = -0.999981		Correlation = -0.999985		Correlation = -0.999981		Correlation = -0.999983	
°F	ρ	°F	ρ	°F	ρ	°F	ρ
32.97	0.78856	32.87	0.77228	32.87	0.76536	32.87	0.77946
45.20	0.78318	45.20	0.76651	45.19	0.75939	45.19	0.77365
54.71	0.77902	54.71	0.76232	54.76	0.75505	54.76	0.76943
59.91	0.77678	59.91	0.76007	59.90	0.75274	59.90	0.76719
65.09	0.77446	65.09	0.75774	65.09	0.75032	65.09	0.76480
74.90	0.77007	74.90	0.75336	74.90	0.74581	74.90	0.76043
85.02	0.76559	85.02	0.74885	85.02	0.74110	85.02	0.75586
95.20	0.76109	95.20	0.74426	95.20	0.73640	95.20	0.75128
105.12	0.75660	105.11	0.73980	105.11	0.73176	105.11	0.74674
119.59	0.75005	119.59	0.73325	119.60	0.72491	119.60	0.74013

(continued)

643[a]		644[a]		83-POSF-0914		83-POSF-0915	
Calculated at 60°F = 0.75402		Calculated at 60°F = 0.76050		Calculated at 60°F = 0.75597		Calculated at 60°F = 0.77937	
Correlation = -0.999986		Correlation = -0.999987		Correlation = -0.999991		Correlation = -0.999984	
°F	ρ	°F	ρ	°F	ρ	°F	ρ
32.87	0.76644	32.87	0.77298	32.95	0.76840	32.95	0.79138
45.19	0.76062	45.19	0.76715	44.51	0.76312	44.51	0.78626
54.76	0.75636	54.76	0.76285	55.26	0.75824	55.26	0.78153
59.90	0.75408	59.90	0.76056	59.58	0.75619	59.58	0.77958
65.09	0.75171	65.09	0.75816	65.03	0.75368	65.03	0.77710
74.90	0.74728	74.90	0.75373	74.19	0.74945	74.19	0.77310
85.02	0.74269	85.02	0.74912	84.40	0.74472	84.40	0.76852
95.20	0.73805	95.20	0.74445	95.77	0.73940	95.77	0.76338
105.11	0.73349	105.11	0.73993	105.08	0.73504	105.08	0.75921
119.60	0.72683	119.60	0.73318	119.39	0.72848	120.76	0.75204

83-POSF-0916		83-POSF-0917		83-POSF-0918		83-POSF-0919	
Calculated at 60°F = 0.76321		Calculated at 60°F = 0.76205		Calculated at 60°F = 0.75287		Calculated at 60°F = 0.75230	
Correlation = -0.999986		Correlation = -0.999962		Correlation = -0.999989		Correlation = -0.999985	
°F	ρ	°F	ρ	°F	ρ	°F	ρ
32.95	0.77512	32.95	0.77378	32.95	0.76495	32.95	0.76434
44.51	0.77007	44.51	0.76897	44.51	0.75981	44.51	0.75923
55.26	0.76535	55.26	0.76425	55.26	0.75501	55.26	0.75442
59.58	0.76343	59.58	0.76230	59.58	0.75308	59.58	0.75255
65.03	0.76101	65.03	0.75988	65.03	0.75065	65.03	0.75008
74.19	0.75696	74.19	0.75584	74.19	0.74656	74.19	0.74596
84.40	0.75243	84.40	0.65130	84.40	0.74197	84.43	0.74140
95.77	0.74733	95.77	0.74617	95.77	0.73682	95.84	0.73623
105.08	0.74317	105.08	0.74199	105.08	0.73259	105.04	0.73203
120.76	0.73609	119.39	0.73577	119.39	0.72607	119.39	0.72550

(continued)

83-POSF-0920

Calculated at 60°F = 0.78029
Correlation = -0.999994

°F	ρ
32.95	0.79236
44.51	0.78724
55.26	0.78242
59.58	0.78048
65.03	0.77808
74.19	0.77397
84.43	0.76942
95.84	0.76420
105.04	0.76005
119.39	0.75365

83-POSF-0921

Calculated at 60°F = 0.76931
Correlation = -0.999988

°F	ρ
32.95	0.78129
44.51	0.77621
55.26	0.77145
59.58	0.76952
65.03	0.76709
74.19	0.76302
84.43	0.75847
95.48	0.75337
105.04	0.74920
120.76	0.74208

83-POSF-0922

Calculated at 60°F = 0.76367
Correlation = -0.999984

°F	ρ
32.95	0.77545
44.51	0.77041
55.26	0.76580
59.58	0.76384
65.03	0.76144
74.19	0.75742
84.43	0.75295
95.84	0.74790
105.04	0.74377
120.76	0.73676

83-POSF-0923

Calculated at 60°F = 0.76543
Correlation = -0.999992

°F	ρ
32.95	0.77743
44.51	0.77236
55.26	0.76757
59.58	0.76563
65.03	0.76322
74.19	0.75913
84.43	0.75456
95.84	0.74942
105.04	0.74521
119.99	0.73859

83-POSF-0924

Calculated at 60°F = 0.75824
Correlation = -0.999994

°F	ρ
32.89	0.77024
44.88	0.76495
55.24	0.76032
60.23	0.75818
64.39	0.75633
74.82	0.75168
84.64	0.74729
95.43	0.74251
104.39	0.73855
119.54	0.73170

83-POSF-0925

Calculated at 60°F = 0.77287
Correlation = -0.999992

°F	ρ
32.89	0.78464
44.88	0.77957
55.24	0.77497
60.23	0.77278
64.39	0.77097
74.82	0.76641
84.64	0.76207
95.43	0.75732
104.39	0.75344
119.54	0.74675

83-POSF-0926

Calculated at 60°F = 0.76683
Correlation = -0.999954

°F	ρ
33.08	0.77871
44.56	0.77370
54.52	0.76929
59.81	0.76696
65.21	0.76449
74.88	0.76022
85.62	0.75553
95.88	0.75090
105.46	0.74658
119.99	0.74062

83-POSF-0927

Calculated at 60°F = 0.75911
Correlation = -0.999987

°F	ρ
33.08	0.77111
44.56	0.76607
54.52	0.76159
59.81	0.75927
65.21	0.75675
74.88	0.75242
85.62	0.74766
95.88	0.74299
105.46	0.73863
120.81	0.73165

(continued)

83-POSF-0928

Calculated at
60°F = 0.76712
Correlation = -0.999993

°F	ρ
33.08	0.77899
44.56	0.77400
54.52	0.76958
59.81	0.76726
65.21	0.76477
74.88	0.76050
85.62	0.75582
95.88	0.75120
105.46	0.74691
120.06	0.74047

83-POSF-0929

Calculated at
60°F = 0.76566
Correlation = -0.999988

°F	ρ
33.08	0.77757
44.56	0.77255
54.52	0.76817
59.81	0.76578
65.21	0.76333
74.88	0.75904
85.62	0.75432
95.88	0.74968
105.46	0.74538
120.81	0.73843

83-POSF-0930

Calculated at
60°F = 0.76898
Correlation = -0.999992

°F	ρ
33.01	0.78099
44.56	0.77572
54.70	0.77127
59.75	0.76908
65.32	0.76667
74.33	0.76267
84.13	0.75834
95.48	0.75329
105.40	0.74887
120.36	0.74226

83-POSF-0931

Calculated at
60°F = 0.76491
Correlation = -0.999992

°F	ρ
33.01	0.77697
44.56	0.77168
54.70	0.76723
59.75	0.76500
65.32	0.76260
74.33	0.75858
84.13	0.75423
95.48	0.74914
105.40	0.74470
120.36	0.73806

83-POSF-0932

Calculated at
60°F = 0.77426
Correlation = -0.999992

°F	ρ
33.01	0.78596
44.56	0.78091
54.70	0.77655
59.75	0.77439
65.32	0.77203
74.33	0.76807
84.13	0.76382
95.48	0.75886
105.40	0.75449
120.06	0.74827

83-POSF-0933

Calculated at
60°F = 0.75768
Correlation = -0.999993

°F	ρ
33.01	0.76979
44.56	0.76456
54.70	0.76004
59.75	0.75778
65.32	0.75537
74.35	0.75127
84.13	0.74687
95.48	0.74171
105.40	0.73722
120.06	0.73072

83-POSF-0934

Calculated at
60°F = 0.76643
Correlation = -0.999995

°F	ρ
33.01	0.77841
44.56	0.77321
54.70	0.76878
59.75	0.76654
65.32	0.76412
74.35	0.76008
84.13	0.75578
95.48	0.75069
105.40	0.74629
120.36	0.73961

83-POSF-0935

Calculated at
60°F = 0.77346
Correlation = -0.999993

°F	ρ
33.01	0.78583
44.56	0.78050
54.70	0.77591
59.75	0.77357
65.32	0.77108
74.35	0.76692
84.13	0.76242
95.48	0.75713
105.40	0.75252
119.98	0.74585

(continued)

83-POSF-0936

Calculated at
60°F = 0.76547
Correlation = -0.999996

°F	ρ
33.01	0.77747
44.56	0.77229
54.70	0.76784
59.75	0.76556
65.29	0.76314
74.35	0.75912
84.13	0.75478
95.51	0.74967
105.40	0.74522
119.98	0.73883

83-POSF-0937

Calculated at
60°F = 0.77754
Correlation = -0.999995

°F	ρ
33.03	0.78966
44.55	0.78446
54.69	0.77995
59.75	0.77764
65.29	0.77519
74.35	0.77114
84.11	0.76672
95.51	0.76159
105.39	0.75706
119.98	0.75049

83-POSF-0938

Calculated at
60°F = 0.75414
Correlation = -0.999991

°F	ρ
33.03	0.76655
44.55	0.76120
54.69	0.75658
59.75	0.75427
65.29	0.75177
74.35	0.74759
84.11	0.74307
95.51	0.73777
105.39	0.73316
119.98	0.72640

83-POSF-0939

Calculated at
60°F = 0.75603
Correlation = -0.999988

°F	ρ
33.03	0.76819
44.55	0.76297
54.69	0.75842
59.75	0.75616
65.29	0.75373
74.35	0.74957
84.11	0.74518
95.51	0.73994
105.39	0.73541
119.98	0.72876

83-POSF-0940

Calculated at
60°F = 0.76438
Correlation = -0.999991

°F	ρ
33.03	0.77677
44.55	0.77141
54.69	0.76680
59.75	0.76451
65.29	0.76200
74.35	0.75782
84.11	0.75331
95.51	0.74801
105.39	0.74362
120.04	0.73673

83-POSF-0941

Calculated at
60°F = 0.75694
Correlation = -0.999993

°F	ρ
33.03	0.76907
44.55	0.76388
54.69	0.75933
59.75	0.75706
65.29	0.75462
74.35	0.75051
84.11	0.74609
95.51	0.74091
105.39	0.73637
120.04	0.72987

83-POSF-0997

Calculated at
60°F = 0.75222
Correlation = -0.999987

°F	ρ
32.47	0.76445
44.98	0.75891
54.72	0.75453
60.36	0.75209
65.21	0.74991
74.96	0.74561
84.86	0.74119
94.65	0.73681
104.52	0.73233
119.96	0.72533

83- POSF-0999

Calculated at
60°F = 0.75765
Correlation = -0.99987

°F	ρ
32.47	0.76990
44.98	0.76434
54.72	0.75998
60.36	0.75753
65.21	0.75536
74.96	0.75102
84.86	0.74657
94.65	0.74220
104.52	0.73772
119.96	0.73069

(continued)

83-POSF-1001

Calculated at
60°F = 0.76471
Correlation = -0.999989

°F	ρ
32.47	0.77698
44.98	0.77141
54.72	0.76708
60.36	0.76457
65.21	0.76241
74.96	0.75806
84.86	0.75360
94.65	0.74920
104.52	0.74475
119.96	0.73770

83-POSF-1019

Calculated at
60°F = 0.75634
Correlation = -0.999982

°F	ρ
32.47	0.76886
44.98	0.76318
54.72	0.75880
60.36	0.75621
65.21	0.75397
74.96	0.74957
84.86	0.74503
94.62	0.74051
104.52	0.73594
119.96	0.72871

83-POSF-1021

Calculated at
60°F = 0.76561
Correlation = -0.999991

°F	ρ
32.47	0.77773
44.98	0.77223
54.72	0.76796
60.36	0.76548
65.11	0.76341
74.96	0.75903
84.86	0.75464
94.65	0.75028
104.52	0.74589
119.96	0.73896

83-POSF-1087

Calculated at
60°F = 0.75995
Correlation = -0.999984

°F	ρ
32.47	0.77261
44.98	0.76686
54.71	0.76241
60.36	0.75982
65.11	0.75767
74.97	0.75308
84.86	0.74848
94.65	0.74392
104.51	0.73934
119.96	0.73203

83-POSF-1088

Calculated at
60°F = 0.76006
Correlation = -0.999983

°F	ρ
33.08	0.77240
44.56	0.76723
54.52	0.76263
59.81	0.76021
65.21	0.75759
74.88	0.75318
85.62	0.74830
95.88	0.74347
105.46	0.73900
120.04	0.73213

83-POSF-1089

Calculated at
60°F = 0.76132
Correlation = -0.999986

°F	ρ
32.47	0.77355
45.00	0.76799
54.71	0.76370
60.36	0.76119
65.11	0.75912
74.97	0.75468
84.86	0.75024
94.65	0.74585
104.51	0.74141
119.96	0.73437

83-POSF-1090

Calculated at
60°F = 0.76148
Correlation = -0.999989

°F	ρ
33.08	0.77340
44.56	0.76839
54.52	0.76394
59.81	0.76161
65.21	0.75909
74.88	0.75483
85.62	0.75012
95.88	0.74548
105.49	0.74132
120.05	0.73468

83-POSF-1091

Calculated at
60°F = 0.76184
Correlation = -0.999987

°F	ρ
32.47	0.77427
45.00	0.76859
54.71	0.76424
60.36	0.76172
65.08	0.75958
74.97	0.75511
84.86	0.75061
94.65	0.74613
104.51	0.74165
119.96	0.73449

(continued)

83-POSF-1092

Calculated at
60°F = 0.76189
Correlation = -0.999990

°F	ρ
33.12	0.77400
44.64	0.76892
54.57	0.76438
59.74	0.76201
65.21	0.75948
74.88	0.75516
85.62	0.75033
95.88	0.74565
105.48	0.74123
120.05	0.73456

83-POSF-1093

Calculated at
60°F = 0.75591
Correlation = -0.999995

°F	ρ
32.89	0.76794
44.88	0.76268
54.73	0.75823
60.23	0.75581
64.39	0.75394
74.82	0.74937
84.64	0.74493
95.76	0.73998
104.39	0.73616
119.54	0.72932

83-POSF-1094

Calculated at
60°F = 0.75594
Correlation = -0.999988

°F	ρ
33.12	0.76779
44.64	0.76280
54.57	0.75842
59.74	0.75606
65.21	0.75355
74.88	0.74933
85.62	0.74466
95.85	0.74001
105.49	0.73581
120.05	0.72924

83-POSF-1095

Calculated at
60°F = 0.76357
Correlation = -0.999984

°F	ρ
32.47	0.77594
45.00	0.77031
54.71	0.76597
60.36	0.76342
65.08	0.76131
74.97	0.75685
84.86	0.75237
94.65	0.74795
104.51	0.74346
119.96	0.73633

83-POSF-1096

Calculated at
60°F = 0.76354
Correlation = -0.999990

°F	ρ
33.12	0.77557
44.64	0.77051
54.57	0.76603
59.74	0.76367
65.21	0.76116
74.88	0.75687
85.62	0.75204
95.85	0.74741
105.48	0.74301
120.05	0.73637

83-POSF-1097

Calculated at
60°F = 0.75325
Correlation = -0.999986

°F	ρ
32.89	0.76576
44.88	0.76027
55.24	0.75549
60.23	0.75315
64.39	0.75126
74.82	0.74644
84.64	0.74181
95.76	0.73659
104.39	0.73260
119.54	0.72541

83-POSF-1098

Calculated at
60°F = 0.75332
Correlation = -0.999987

°F	ρ
33.12	0.76574
44.64	0.76052
54.57	0.75592
59.74	0.75347
65.21	0.75085
74.88	0.74641
85.62	0.74140
95.85	0.73662
105.49	0.73209
120.05	0.72518

83-POSF-1157

Calculated at
60°F = 0.76113
Correlation = -0.999992

°F	ρ
33.31	0.77290
44.58	0.76794
54.81	0.76343
59.77	0.76127
65.49	0.75896
75.04	0.75452
85.10	0.74998
94.59	0.74582
104.48	0.74140
119.27	0.73475

(continued)

83-POSF-1181	
Calculated at 60°F = 0.76133	
Correlation = -0.999991	
°F	ρ
33.31	0.77315
44.58	0.76816
54.81	0.76363
59.77	0.76145
65.31	0.76094
75.04	0.75468
85.10	0.75018
94.59	0.74598
104.48	0.74153
119.27	0.73485

83-POSF-1283	
Calculated at 60°F = 0.76054	
Correlation = -0.999980	
°F	ρ
33.31	0.78018
44.58	0.77524
54.81	0.77076
59.77	0.76861
65.49	0.76610
75.04	0.76188
85.10	0.75741
94.59	0.75326
104.48	0.74885
119.27	0.74224

84-POSF-1793	
Calculated at 60°F = 0.75121	
Correlation = -0.999983	
°F	ρ
32.16	0.76410
45.12	0.75814
54.89	0.75363
60.28	0.75111
65.18	0.74882
74.96	0.74429
84.89	0.73966
94.70	0.73507
104.61	0.73038
120.02	0.72304

84-POSF-1794	
Calculated at 60°F = 0.76112	
Correlation = -0.999992	
°F	ρ
32.16	0.77348
45.12	0.76779
54.89	0.76344
60.28	0.76097
65.18	0.75883
74.98	0.75448
84.89	0.74995
94.70	0.74568
104.61	0.74124
120.11	0.73422

84-POSF-1795	
Calculated at 60°F = 0.75614	
Correlation = -0.999987	
°F	ρ
32.18	0.76914
45.14	0.76313
54.89	0.75858
60.31	0.75601
65.19	0.75373
74.98	0.74914
84.89	0.74447
94.71	0.73986
104.64	0.73512
120.11	0.72770

84-POSF-1796	
Calculated at 60°F = 0.76333	
Correlation = -0.999993	
°F	ρ
32.18	0.77565
45.14	0.76994
54.89	0.76566
60.31	0.76320
65.19	0.76102
74.98	0.75668
84.89	0.75230
94.71	0.74790
104.64	0.74345
120.11	0.73548

84-POSF-1954	
Calculated at 60°F = 0.76275	
Correlation = -0.999994	
°F	ρ
33.11	0.77461
45.23	0.76927
54.93	0.76501
59.77	0.76283
65.31	0.76043
75.04	0.75612
85.10	0.75167
95.06	0.74723
105.16	0.74276
119.92	0.73611

84-POSF-1955	
Calculated at 60°F = 0.76292	
Correlation = -0.999994	
°F	ρ
33.11	0.77480
45.23	0.76943
54.93	0.76517
59.77	0.76301
65.31	0.76060
75.04	0.75630
85.10	0.75185
95.06	0.74743
105.16	0.74293
119.93	0.73354

(continued)

84-POSF-1956	
Calculated at 60°F = 0.76256	
Correlation = -0.999991	
°F	ρ
33.08	0.77446
45.23	0.76909
54.93	0.76481
59.77	0.76264
65.31	0.76025
75.04	0.75591
85.10	0.75146
95.06	0.74705
105.16	0.74253
119.92	0.73585

84-POSF-1957	
Calculated at 60°F = 0.76327	
Correlation = -0.999993	
°F	ρ
33.08	0.77524
45.23	0.76983
54.93	0.76553
59.78	0.76339
65.31	0.76094
75.04	0.75659
85.10	0.75212
95.06	0.74766
105.16	0.74314
119.92	0.73644

84-POSF-1958	
Calculated at 60°F = 0.76054	
Correlation = -0.999980	
°F	ρ
32.77	0.77296
45.28	0.76705
54.93	0.76276
59.78	0.76957
65.31	0.75814
75.04	0.75379
85.10	0.74928
95.06	0.74482
105.16	0.74024
119.93	0.73354

84-POSF-1959	
Calculated at 60°F = 0.75818	
Correlation = -0.999982	
°F	ρ
32.77	0.77041
45.28	0.76461
54.93	0.76037
59.78	0.75821
65.31	0.75581
75.04	0.75154
85.10	0.74707
95.06	0.74269
105.28	0.73808
119.93	0.73354

84-POSF-1960	
Calculated at 60°F = 0.75142	
Correlation = -0.999982	
°F	ρ
32.77	0.76411
45.28	0.75809
54.93	0.75369
59.78	0.75148
65.31	0.74898
75.04	0.74447
85.10	0.73988
95.06	0.73533
105.28	0.73056
119.93	0.72371

84-POSF-1961	
Calculated at 60°F = 0.75818	
Correlation = -0.999982	
°F	ρ
33.31	0.76718
44.58	0.76209
54.81	0.75750
59.77	0.75526
65.49	0.75269
75.04	0.74832
85.10	0.74372
94.59	0.73943
104.48	0.73487
119.27	0.72805

84-POSF-1962	
Calculated at 60°F = 0.75142	
Correlation = -0.999982	
°F	ρ
33.31	0.76515
44.58	0.76014
54.81	0.75556
59.77	0.75337
65.49	0.75083
75.04	0.74653
85.10	0.74199
94.59	0.73774
104.48	0.73325
119.27	0.72650

84-POSF-1963	
Calculated at 60°F = 0.76828	
Correlation = -0.999988	
°F	ρ
33.31	0.78014
44.58	0.77515
54.81	0.77060
59.77	0.76843
65.49	0.76588
75.04	0.76159
85.10	0.75705
94.59	0.75283
104.48	0.74836
119.27	0.74162

APPENDIX C

TEMPERATURE-DENSITY DATA ON 24 FUEL SAMPLES

JP-7		JP-5		JP-4		DF-Marine	
82-POSF-026		82-POSF-0155		82-POSF-0159		82-POSF-0184	
Calculated at 60°F = 0.79933		Calculated at 60°F = 0.81828		Calculated at 60°F = 0.75993		Calculated at 60°F = 0.84530	
Correlation = -0.999972		Correlation = -0.999997		Correlation = -0.999977		Correlation = -0.999984	
°F	ρ	°F	ρ	°F	ρ	°F	ρ
32.63	0.81020	32.60	0.82935	32.60	0.77205	32.63	0.85610
44.98	0.80535	44.92	0.82438	44.92	0.76660	44.98	0.85126
54.75	0.80141	54.79	0.82039	54.79	0.76230	54.75	0.84737
59.68	0.79948	59.69	0.81844	59.69	0.76012	59.68	0.84544
65.20	0.79727	65.16	0.81620	65.16	0.75769	65.20	0.84325
74.64	0.79351	74.41	0.81246	74.41	0.75359	74.64	0.83952
84.44	0.78960	84.77	0.80825	84.77	0.74886	84.44	0.83565
94.67	0.78551	94.93	0.80416	94.93	0.74437	94.67	0.83160
105.08	0.78131	105.06	0.79999	105.06	0.73975	105.08	0.82742
120.13	0.77504	119.90	0.79395	119.90	0.73302	120.13	0.82128

JP-5		JP-4		Shale Crude	JP-5	
82-POSF-0314		82-POSF-0323		82-POSF-0325	82-POSF-0443	
Calculated at 60°F = 0.82361		Calculated at 60°F = 0.77997		Sample too viscous for measurement	Calculated at 60°F = 0.81261	
Correlation = -0.999974		Correlation = -0.999982			Correlation = -0.999988	
°F	ρ	°F	ρ		°F	ρ
32.63	0.83462	32.61	0.79217		32.63	0.82360
44.98	0.82965	44.92	0.78668		44.98	0.81864
54.75	0.82574	54.79	0.78234		54.75	0.81471
59.68	0.82375	59.69	0.78014		59.68	0.81275
65.20	0.82153	65.16	0.77772		65.20	0.81054
74.64	0.81773	74.41	0.77360		74.64	0.80675
84.44	0.81377	84.77	0.76885		84.44	0.80280
94.67	0.80964	94.93	0.76434		94.67	0.79868
105.08	0.80535	105.06	0.75972		105.08	0.79440
120.13	0.79905	119.90	0.75295		120.13	0.78812

(continued)

Shale JP-8
82-POSF-0562
Calculated at
60°F = 0.80322
Correlation = -0.999967

°F	ρ
32.63	0.81444
44.98	0.80937
54.75	0.80537
59.68	0.80336
65.20	0.80111
74.64	0.79724
84.44	0.79320
94.67	0.78900
105.08	0.78462
120.20	0.77814

Jet A
83-POSF-0709
Calculated at
60°F = 0.81167
Correlation = -0.999978

°F	ρ
32.63	0.82269
44.98	0.81773
54.75	0.81378
59.68	0.81180
65.20	0.80958
74.64	0.80578
84.44	0.80183
94.67	0.79771
105.08	0.79341
120.20	0.78710

DF-2
83-POSF-1051
Calculated at
60°F = 0.84178
Correlation = -0.999992

°F	ρ
32.63	0.85232
44.91	0.84757
54.75	0.84379
59.70	0.84190
65.20	0.83979
74.64	0.83618
84.20	0.83242
94.66	0.82847
105.01	0.82440
120.20	0.81846

Jet A
83-POSF-1254
Calculated at
60°F = 0.81005
Correlation = -0.999980

°F	ρ
32.60	0.82116
44.91	0.81619
54.75	0.81220
59.70	0.81022
65.20	0.80797
74.64	0.80413
84.20	0.80017
94.66	0.79599
105.01	0.79168
120.13	0.78534

Jet A
83-POSF-1257
Calculated at
60°F = 0.81004
Correlation = -0.999996

°F	ρ
32.61	0.82114
44.92	0.81614
54.79	0.81216
59.69	0.81019
65.16	0.80796
74.41	0.80422
84.77	0.79999
94.93	0.79587
105.06	0.79174
119.90	0.78563

Jet A
83-POSF-1260
Calculated at
60°F = 0.81345
Correlation = -0.999997

°F	ρ
32.61	0.82446
44.92	0.81952
54.79	0.81557
59.69	0.81360
65.27	0.81131
74.41	0.80767
84.77	0.80349
94.93	0.79940
105.06	0.79530
119.90	0.78925

Jet A
83-POSF-1530
Calculated at
60°F = 0.79597
Correlation = -0.999976

°F	ρ
32.60	0.80729
44.91	0.80221
54.75	0.79816
59.70	0.79613
65.20	0.79386
74.64	0.78996
84.20	0.78591
94.66	0.78165
105.01	0.77725
120.13	0.77078

Jet A
83-POSF-1723
Calculated at
60°F = 0.81277
Correlation = -0.999997

°F	ρ
32.61	0.82389
44.96	0.81889
54.79	0.81491
59.69	0.81292
65.27	0.81064
74.41	0.80693
84.77	0.80269
94.93	0.79856
105.06	0.79443
119.90	0.78831

(continued)

JP-7
84-POSF-2003

Calculated at $60°F = 0.79754$
Correlation = -0.999997

°F	ρ
32.61	0.80841
44.96	0.80351
54.78	0.79963
59.68	0.79769
65.27	0.79545
74.41	0.79184
84.80	0.78769
94.92	0.78366
105.06	0.77961
119.89	0.77365

JP-8
84-POSF-2035

Calculated at $60°F = 0.79871$
Correlation = -0.999981

°F	ρ
32.60	0.80990
44.91	0.80488
54.75	0.80087
59.70	0.79886
65.20	0.79662
74.64	0.79277
84.20	0.78876
94.66	0.78457
105.01	0.78022
120.20	0.77383

JP-8
84-POSF-2038

Calculated at $60°F = 0.80155$
Correlation = -0.999986

°F	ρ
32.60	0.81290
44.92	0.80782
54.75	0.80373
59.70	0.80170
65.20	0.79943
74.64	0.79551
84.20	0.79144
94.66	0.78717
105.01	0.78275
120.00	0.77641

JP-5
84-POSF-2071

Calculated at $60°F = 0.80593$
Correlation = -0.999997

°F	ρ
32.61	0.81694
44.96	0.81198
54.78	0.80804
59.68	0.80608
65.27	0.80381
74.41	0.80015
84.80	0.79594
94.92	0.79185
105.06	0.78775
119.89	0.78171

JPTS
84-POSF-2075

Calculated at $60°F = 0.79483$
Correlation = -0.999987

°F	ρ
32.60	0.80605
44.92	0.80102
54.75	0.79700
59.70	0.79497
65.20	0.79272
74.64	0.78886
84.20	0.78484
94.66	0.78062
105.01	0.77625
120.00	0.76999

Gasoline
84-POSF-2078

This sample so volatile that density measurements could not be made, even at temperatures as low as 32°F.

Gasoline
84-POSF-2079

This sample so volatile that density measurements could not be made even at temperatures as low as 32°F.

Gasoline
84-POSF-2080

Calculated at $60°F = 0.75056$
Correlation = -0.999098

°F	ρ
32.62	0.76371
44.96	0.75749
54.78	0.75359
59.68	Bubbles
65.27	Bubbles
74.41	0.74423
84.80	0.73789
94.92	0.73363
105.06	Bubbles
119.89	Bubbles

APPENDIX D

COEFFICIENT OF THERMAL EXPANSION AND DENSITY VALUES FOR MISCELLANEOUS FUELS AT 60°F

Sample No.	Alpha Value at 60°F	Density (kg/m^3)	Type of fuel	Nearest Group
26	499.32	799.35	JP-7	Jet
155	493.24	818.31	JP-5	Jet
159	585.32	759.96	JP-4	Crude
184	467.92	845.32	DF-Marine	Jet
314	490.20	823.63	JP-5	Jet
323	572.86	780.00	JP-4	Crude
443	495.45	812.63	JP-5	Jet
562	512.12	803.24	JP-8 (shale)	Jet
709	497.25	811.69	Jet A	Jet
1051	456.70	841.80	DF-2	Jet
1254	502.19	810.08	Jet A	Jet
1257	499.45	810.07	Jet A	Jet
1260	493.31	813.48	Jet A	Jet
1530	520.64	796.00	Jet A	Jet
1723	499.01	812.80	Jet A	Jet
2003	496.84	797.57	JP-7	Jet
2035	512.32	798.74	JP-8	Jet
2038	518.16	801.58	JP-8	Jet
2071	498.38	805.95	JP-5	Jet
2075	516.37	794.85	JPTS	Jet
2080	645.52	750.61	Gasoline	Crude

U.S. GOVERNMENT PRINTING OFFICE 1988

END

10-86

DTIC